

## Designer's™ Data Sheet

**NPN Silicon Power Transistors****1.5 kV SWITCHMODE Series**

These transistors are designed for high-voltage, high-speed, power switching in inductive circuits where fall time is critical. They are particularly suited for line-operated switchmode applications.

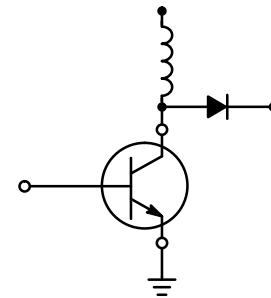
## Typical Applications:

- Switching Regulators
- Inverters
- Solenoids
- Relay Drivers
- Motor Controls
- Deflection Circuits

- Features:
- Collector-Emitter Voltage —  $V_{CEV} = 1500$  Vdc
  - Fast Turn-Off Times
    - 80 ns Inductive Fall Time — 100°C (Typ)
    - 110 ns Inductive Crossover Time — 100°C (Typ)
    - 4.5  $\mu$ s Inductive Storage Time — 100°C (Typ)
  - 100°C Performance Specified for:
    - Reverse-Biased SOA with Inductive Load
    - Switching Times with Inductive Loads
    - Saturation Voltages
    - Leakage Currents

**MJ16018\***  
**MJW16018\***

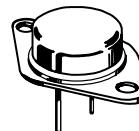
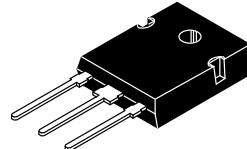
\*Motorola Preferred Device

**POWER TRANSISTORS**  
**10 AMPERES**  
**800 VOLTS**  
**125 AND 175 WATTS**
**MAXIMUM RATINGS**

Rating	Symbol	MJ16018	MJW16018	Unit
Collector-Emitter Voltage	$V_{CEO(sus)}$	800		Vdc
Collector-Emitter Voltage	$V_{CEV}$	1500		Vdc
Emitter-Base Voltage	$V_{EB}$	6		Vdc
Collector Current — Continuous — Peak(1)	$I_C$ $I_{CM}$	10 15		Adc
Base Current — Continuous — Peak(1)	$I_B$ $I_{BM}$	8 12		Adc
Total Power Dissipation @ $T_C = 25^\circ\text{C}$ @ $T_C = 100^\circ\text{C}$ Derate above $T_C = 25^\circ\text{C}$	$P_D$	175 100 1	125 50 1	Watts W/ $^\circ\text{C}$
Operating and Storage Junction Temperature Range	$T_J, T_{Stg}$	-65 to 200	-55 to 150	$^\circ\text{C}$

**THERMAL CHARACTERISTICS**

Characteristic	Symbol	Max		Unit
Thermal Resistance, Junction to Case	$R_{\theta JC}$	1	1	$^\circ\text{C/W}$
Lead Temperature for Soldering Purposes: 1/8" from Case for 5 Seconds	$T_L$	275		$^\circ\text{C}$

(1) Pulse Test: Pulse Width = 5  $\mu\text{s}$ , Duty Cycle  $\leq 10\%$ .
**CASE 1-07**  
**TO-204AA**  
**MJ16018**

**CASE 340F-03**  
**TO-247AE**  
**MJW16018**

**Designer's Data for "Worst Case" Conditions** — The Designer's Data Sheet permits the design of most circuits entirely from the information presented. SOA Limit curves — representing boundaries on device characteristics — are given to facilitate "worst case" design.

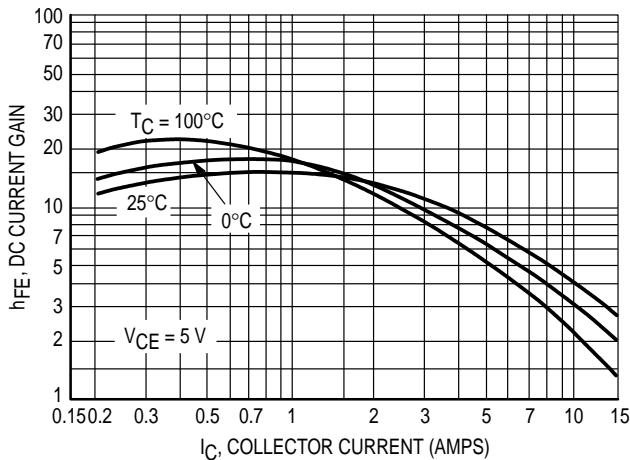
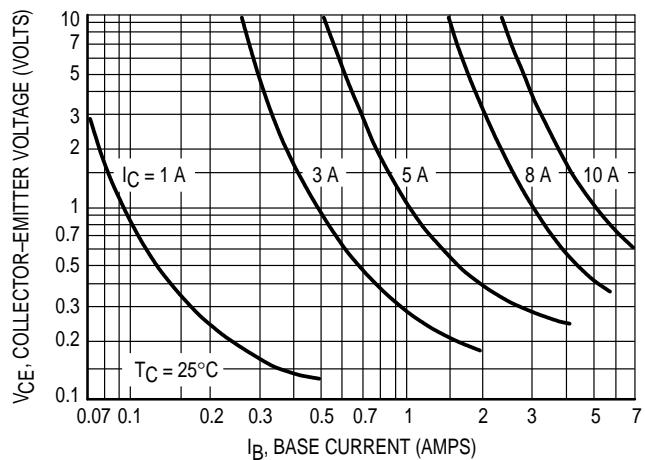
**Preferred** devices are Motorola recommended choices for future use and best overall value.

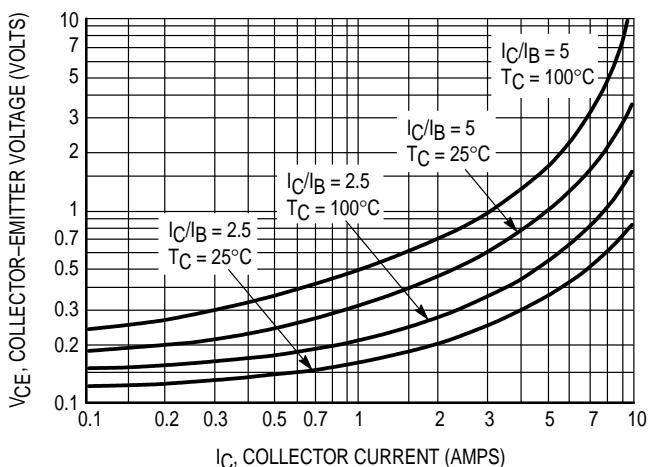
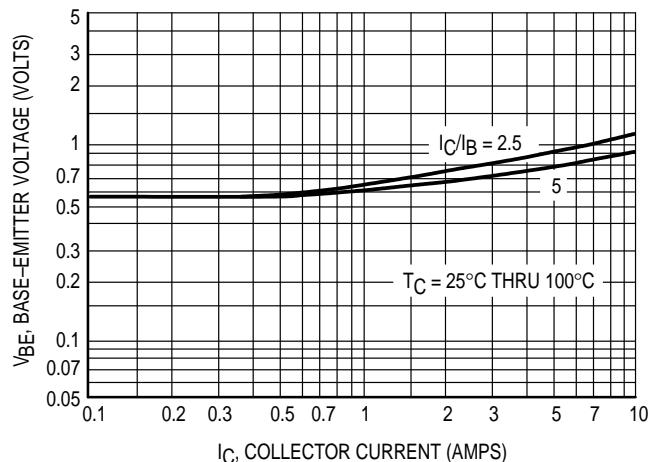
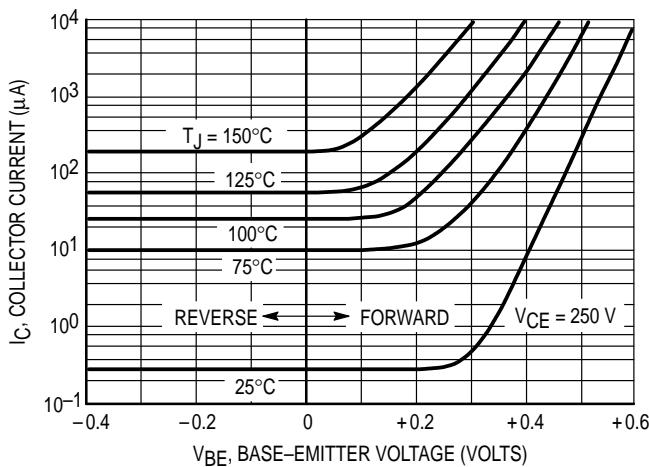
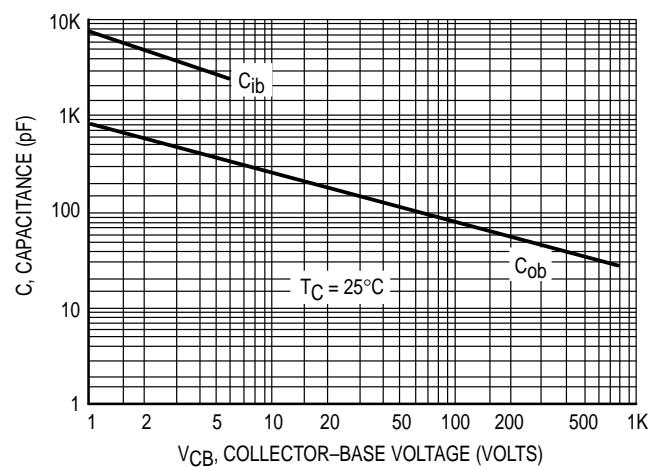
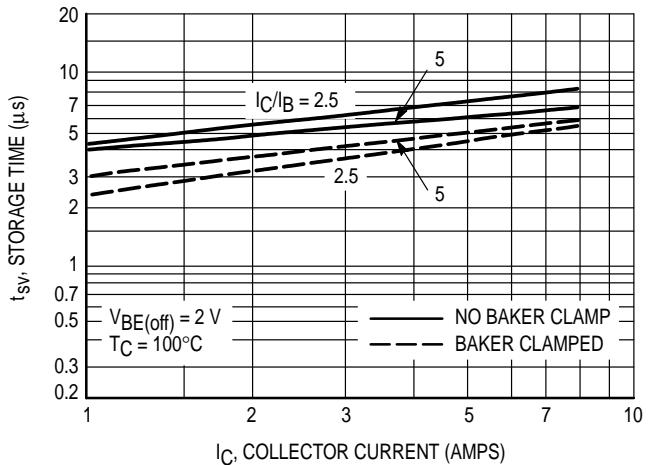
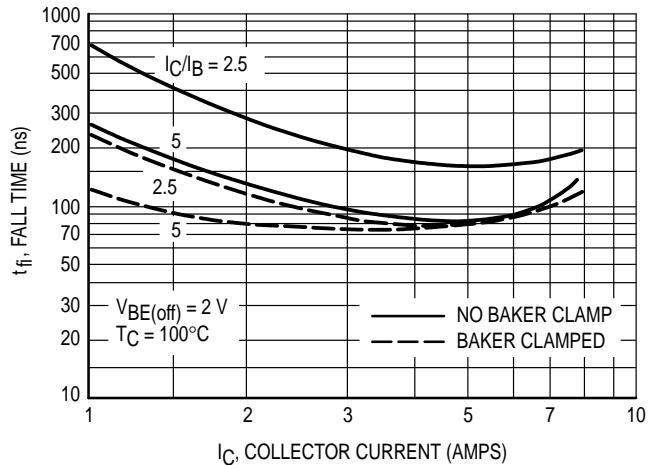
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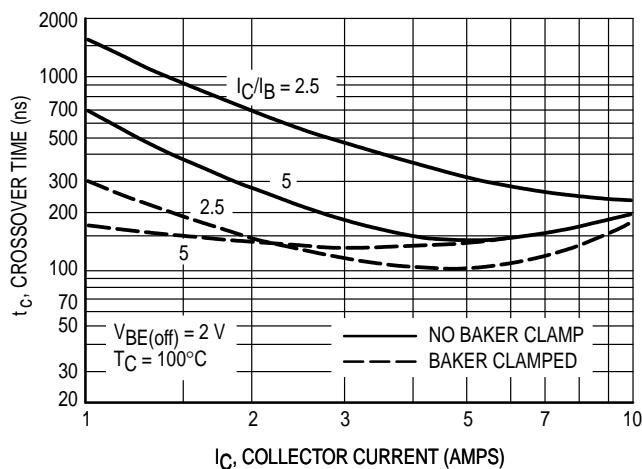
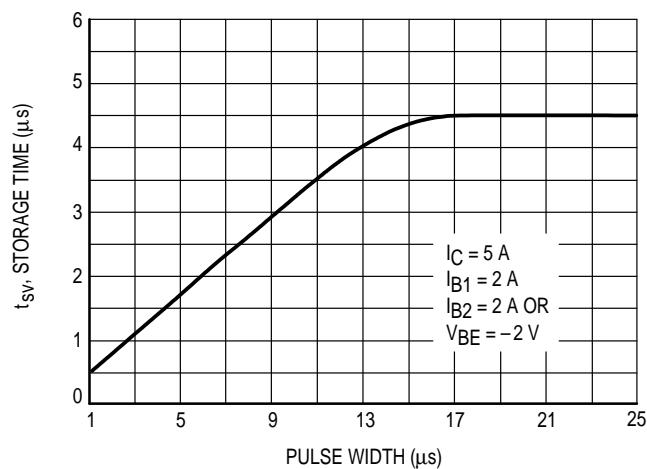
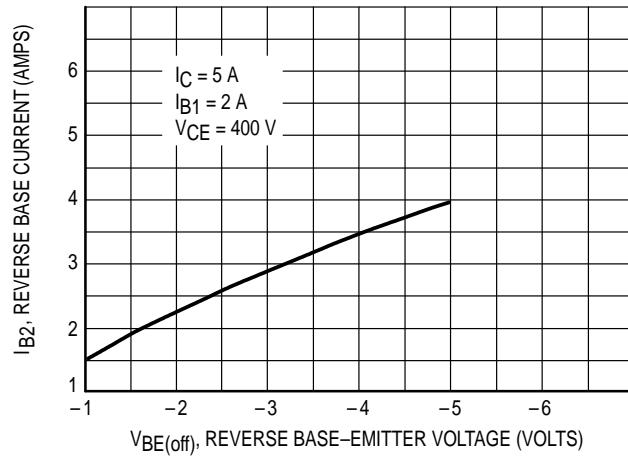
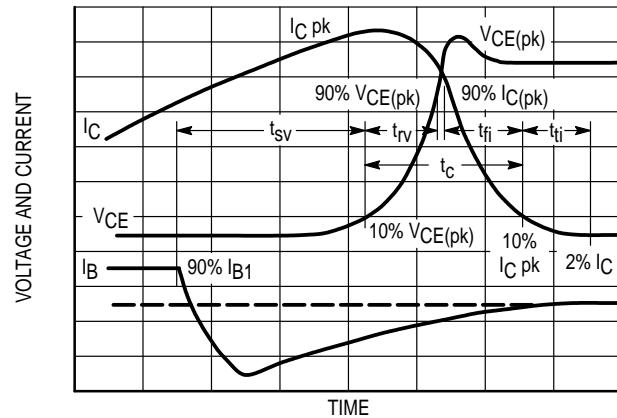
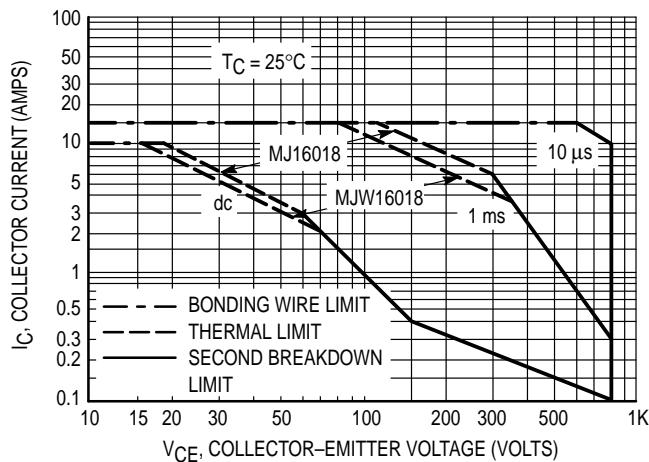
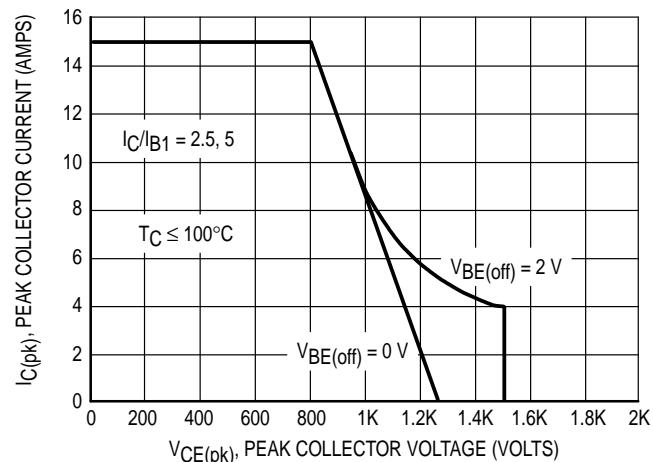
**ELECTRICAL CHARACTERISTICS ( $T_C = 25^\circ\text{C}$  unless otherwise noted)**

Characteristic	Symbol	Min	Typ	Max	Unit		
<b>OFF CHARACTERISTICS(1)</b>							
Collector-Emitter Sustaining Voltage (Table 1) ( $I_C = 50 \text{ mA}$ , $I_B = 0$ )	$V_{CEO(\text{sus})}$	800	—	—	Vdc		
Collector Cutoff Current ( $V_{CEV} = 1500 \text{ Vdc}$ , $V_{BE(\text{off})} = 1.5 \text{ Vdc}$ ) ( $V_{CEV} = 1500 \text{ Vdc}$ , $V_{BE(\text{off})} = 1.5 \text{ Vdc}$ , $T_C = 100^\circ\text{C}$ )	$I_{CEV}$	—	—	0.25 1.5	mAdc		
Collector Cutoff Current ( $V_{CE} = 1500 \text{ Vdc}$ , $R_{BE} = 50 \Omega$ , $T_C = 100^\circ\text{C}$ )	$I_{CER}$	—	—	2.5	mAdc		
Emitter Cutoff Current ( $V_{EB} = 6 \text{ Vdc}$ , $I_C = 0$ )	$I_{EBO}$	—	—	0.1	mAdc		
<b>SECOND BREAKDOWN</b>							
Second Breakdown Collector Current with Base Forward Biased	$I_{S/b}$	See Figure 13					
Clamped Inductive SOA with Base Reverse Biased	RBSOA	See Figure 14					
<b>ON CHARACTERISTICS(1)</b>							
Collector-Emitter Saturation Voltage ( $I_C = 5 \text{ Adc}$ , $I_B = 2 \text{ Adc}$ ) ( $I_C = 10 \text{ Adc}$ , $I_B = 5 \text{ Adc}$ ) ( $I_C = 5 \text{ Adc}$ , $I_B = 2 \text{ Adc}$ , $T_C = 100^\circ\text{C}$ )	$V_{CE(\text{sat})}$	— — —	— — —	1 5 1.5	Vdc		
Base-Emitter Saturation Voltage ( $I_C = 5 \text{ Adc}$ , $I_B = 2 \text{ Adc}$ ) ( $I_C = 5 \text{ Adc}$ , $I_B = 2 \text{ Adc}$ , $T_C = 100^\circ\text{C}$ )	$V_{BE(\text{sat})}$	— —	— —	1.5 1.5	Vdc		
DC Current Gain ( $I_C = 5 \text{ Adc}$ , $V_{CE} = 5 \text{ Vdc}$ )	$h_{FE}$	4	—	—	—		
<b>DYNAMIC CHARACTERISTICS</b>							
Output Capacitance ( $V_{CB} = 10 \text{ Vdc}$ , $I_E = 0$ , $f_{\text{test}} = 1 \text{ kHz}$ )	$C_{ob}$	—	—	450	pF		
<b>SWITCHING CHARACTERISTICS</b>							
<b>Inductive Load (Table 1)</b>							
Storage Time	Baker Clamped ( $I_C = 5 \text{ Adc}$ , $I_{B1} = 2 \text{ Adc}$ , $V_{BE(\text{off})} = 2 \text{ Vdc}$ , $V_{CE(\text{pk})} = 400 \text{ Vdc}$ $PW = 25 \mu\text{s}$ )	$(T_J = 25^\circ\text{C})$	$t_{SV}$	—	4000	8000	ns
Fall Time			$t_{fi}$	—	60	200	
Crossover Time			$t_c$	—	90	300	
Storage Time		$(T_J = 100^\circ\text{C})$	$t_{SV}$	—	4500	9000	
Fall Time			$t_{fi}$	—	80	250	
Crossover Time			$t_c$	—	110	375	
<b>Resistive Load (Table 1)</b>							
Delay Time	Baker Clamped ( $I_C = 5 \text{ Adc}$ , $V_{CC} = 250 \text{ Vdc}$ , $I_{B1} = 2 \text{ Adc}$ , $I_{B2} = 2 \text{ Adc}$ , $R_{B2} = 3 \Omega$ , $PW = 25 \mu\text{s}$ , Duty Cycle $\leq 2\%$ )	$t_d$	—	85	200	ns	
Rise Time		$t_r$	—	900	2000		
Storage Time		$t_s$	—	4500	9000		
Fall Time		$t_f$	—	200	400		

(1) Pulse Test: PW = 300  $\mu\text{s}$ , Duty Cycle  $\leq 2\%$ .


**Figure 1. DC Current Gain**

**Figure 2. Collector Saturation Region**

**TYPICAL STATIC CHARACTERISTICS**

**Figure 3. Collector-Emitter Saturation Region**

**Figure 4. Base-Emitter Saturation Region**

**Figure 5. Collector Cutoff Region**

**Figure 6. Typical Capacitance**
**TYPICAL INDUCTIVE SWITCHING CHARACTERISTICS**

**Figure 7. Storage Time**

**Figure 8. Inductive Switching Fall Time**

**TYPICAL INDUCTIVE SWITCHING CHARACTERISTICS**

**Figure 9. Inductive Switching Crossover Time**

**Figure 10. ( $t_{sv}$ ) Storage Time versus  $I_B1$  Pulse Width**

**Figure 11. Reverse Base Current versus Off Voltage**

**Figure 12. Inductive Switching Measurements**
**GUARANTEED SAFE OPERATING AREA LIMITS**

**Figure 13. Maximum Forward Bias Safe Operating Area**

**Figure 14. Maximum Reverse Bias Safe Operating Area**

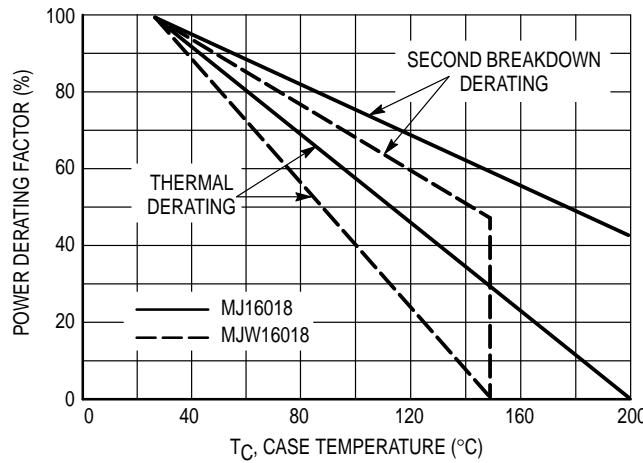


Figure 15. Power Derating

## SAFE OPERATING AREA INFORMATION

### FORWARD BIAS

There are two limitations on the power handling ability of a transistor: average junction temperature and second breakdown. Safe operating area curves indicate  $I_C - V_{CE}$  limits of the transistor that must be observed for reliable operation; i.e., the transistor must not be subjected to greater dissipation than the curves indicate.

The data of Figure 13 is based on  $T_C = 25^\circ\text{C}$ ;  $T_J(\text{pk})$  is variable depending on power level. Second breakdown pulse limits are valid for duty cycles to 10% but must be derated when  $T_C \geq 25^\circ\text{C}$ . Second breakdown limitations do not derate the same as thermal limitations. Allowable current at the voltages shown on Figure 13 may be found at any case temperature by using the appropriate curve on Figure 15.

$T_J(\text{pk})$  may be calculated from the data in Figure 16. At high case temperatures, thermal limitations will reduce the

power that can be handled to values less than the limitations imposed by second breakdown.

### REVERSE BIAS

For inductive loads, high voltage and high current must be sustained simultaneously during turn-off, in most cases, with the base-to-emitter junction reverse biased. Under these conditions the collector voltage must be held to a safe level at or below a specific value of collector current. This can be accomplished by several means such as active clamping, RC snubbing, load line shaping, etc. The safe level for these devices is specified as Reverse Bias Safe Operating Area and represents the voltage current condition allowable during reverse biased turnoff. This rating is verified under clamped conditions so that the device is never subjected to an avalanche mode. Figure 14 gives the RBSOA characteristics.

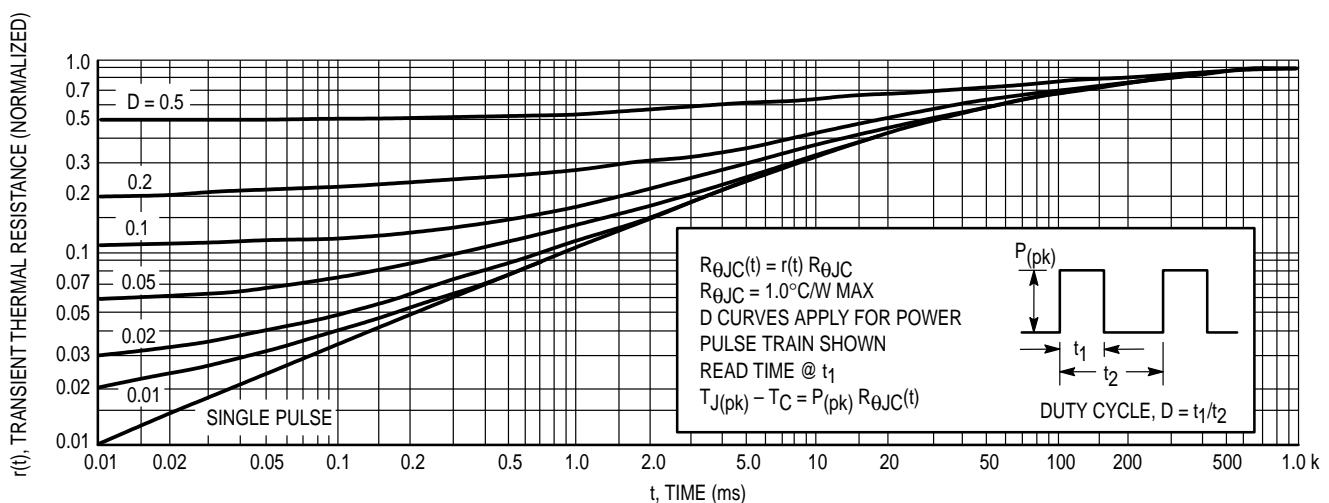
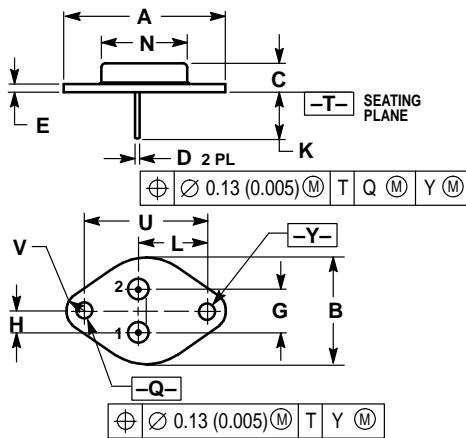


Figure 16. Thermal Response

**Table 1. Test Conditions for Dynamic Performance**

$V_{CEO(sus)}$	RBSOA	Inductive Switching	Resistive Switching
<p><b>Drive Circuit</b></p> <p>Note: Adjust <math>V_{off}</math> to obtain desired <math>V_{BE(off)}</math> at Point A</p>	<p><b>For <math>t_d</math> and <math>t_f</math>:</b></p> <p><b>For <math>t_s</math> and <math>t_f</math>:</b> Inductive Switching Drive Circuit</p>	<p><b>for <math>t_d</math> and <math>t_f</math>:</b> <math>V_{CC} = 250</math> Volts <math>R_B</math> selected for desired <math> B_1 </math> <math>R_L</math> selected for desired <math> C </math></p> <p><b>for <math>t_s</math> and <math>t_f</math>:</b> <math>V_{CC} = 250</math> Volts <math>R_B = 0</math> <math>R_{B1} \&amp; R_{B2}</math> selected for <math> B_1 \&amp;  B_2 </math> <math>R_L</math> selected for desired <math> C </math></p>	<p><math>L = 200 \mu H</math> <math>R_{B2} = 0</math> when <math>V_{BE}(off)</math> is specified or selected for desired <math> B_2 </math> <math>V_{CC} \approx 20</math> Volts, Adjusted to obtain desired IC <math>R_{B1}</math> selected for desired <math> B_1 </math> <math>S_1</math> = Open for baker clamp condition</p>
<p><b>Input Conditions</b></p>	<p><math>L = 10 \text{ mH}</math> <math>R_{B2} = \infty</math> <math>V_{CC} = 20</math> Volts <math>I_{(pk)} = 50</math> mA <math>S_1</math> Closed</p>	<p><math>L = 200 \mu H</math> <math>R_{B2} = 0</math> <math>V_{CC} = 20</math> Volts <math>R_{B1}</math> selected for desired <math> B_1 </math> <math>S_1</math> Closed</p>	<p><b>Test Circuit</b></p> <p><math>T_1 \rightarrow +V</math> <math>T_1 \approx \frac{L_{coil} (I_{C(pk)}}{V_{CC}}</math> <math>I_1</math> adjusted to obtain <math> C_{(pk)}</math></p> <p><b>Scope — Tektronix AM503</b> <b>P6302 or Equivalent</b></p> <p><b>Scope — Tektronix 7403 or Equivalent</b></p> <p><sup>a</sup>Tektronix AM503 P6302 or Equivalent</p>

## PACKAGE DIMENSIONS

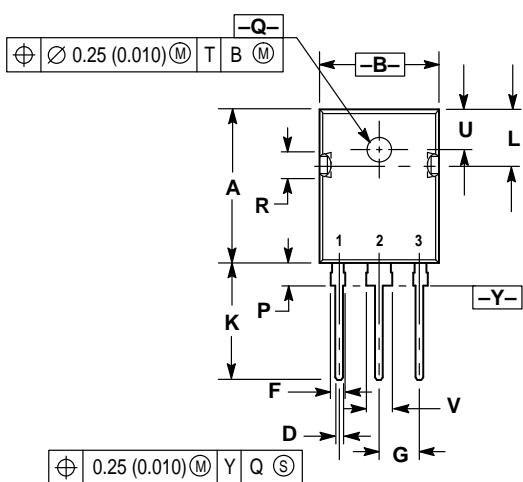


NOTES:  
 1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.  
 2. CONTROLLING DIMENSION: INCH.  
 3. ALL RULES AND NOTES ASSOCIATED WITH REFERENCED TO-204AA OUTLINE SHALL APPLY.

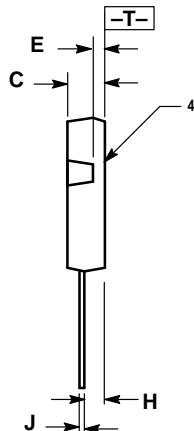
DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	1.550	REF	39.37	REF
B	—	1.050	—	26.67
C	0.250	0.335	6.35	8.51
D	0.038	0.043	0.97	1.09
E	0.055	0.070	1.40	1.77
G	0.430	BSC	10.92	BSC
H	0.215	BSC	5.46	BSC
K	0.440	0.480	11.18	12.19
L	0.665	BSC	16.89	BSC
N	—	0.830	—	21.08
Q	0.151	0.165	3.84	4.19
U	1.187	BSC	30.15	BSC
V	0.131	0.188	3.33	4.77

STYLE 1:  
 PIN 1. BASE  
 2. Emitter  
 CASE: COLLECTOR

CASE 1-07  
 TO-204AA (TO-3)  
 ISSUE Z



NOTES:  
 1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.  
 2. CONTROLLING DIMENSION: MILLIMETER.



DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	20.40	20.90	0.803	0.823
B	15.44	15.95	0.608	0.628
C	4.70	5.21	0.185	0.205
D	1.09	1.30	0.043	0.051
E	1.50	1.63	0.059	0.064
F	1.80	2.18	0.071	0.086
G	5.45	BSC	0.215	BSC
H	2.56	2.87	0.101	0.113
J	0.48	0.68	0.019	0.027
K	15.57	16.08	0.613	0.633
L	7.26	7.50	0.286	0.295
P	3.10	3.38	0.122	0.133
Q	3.50	3.70	0.138	0.145
R	3.30	3.80	0.130	0.150
U	5.30	BSC	0.209	BSC
V	3.05	3.40	0.120	0.134

STYLE 3:  
 PIN 1. BASE  
 2. COLLECTOR  
 3. Emitter  
 4. COLLECTOR

CASE 340F-03  
 TO-247AE  
 ISSUE E

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